Experimental report

03/01/2022

Proposal: **1-05-97** **Council:** 4/2021

Title: Macropore-matrix flow exchange experiments

Research area: Other...

This proposal is a new proposal

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Samples: C2H4O (PEG), H20, D20, organic compounds, clay and silt particles

Instrument	Requested days	Allocated days	From	To
NEXT	3	3	01/09/2021	04/09/2021

Abstract:

Biopores such as earthworm burrows and decayed-root channels can serve as preferential flow paths for water, solute and gas transport processes. Biopore walls are often coated with exudates displaying altered properties when compared to the soil matrix. Such properties control biopore-matrix mass exchange of water and solutes and the preferential flow dynamics. The current mm-scale mass transfer quantification is still methodically limited due to the small spatial size and the heterogeneity of the coatings. Thus, reproducing the water movement between biopore coated surface and the soil matrix and quantifying the structural changes and mass exchange processes at a micrometer scale will be fundamental to determine crack size distribution and water amount along sample profile and time. Such results will be implemented in the development and validation of effective parameters in simplified first-order mass transfer approaches for two-domain flow model descriptions.

Beamtime 01st to 04th September 2021

Experiment 1-05-97

Macropore-matrix flow exchange experiments

Preliminary report

Scientific background

Preferential flow through fissures and macropores has been intensively studied in structured soils and fractured rocks or geologic formations [1]. In soils, shrinkage cracks and biopores such as earthworm burrows and decayed-root channels can serve as preferential flow paths for water, solute and gas transport processes. Biopore walls are often coated with exudates and finer soil particles such that the soil in the vicinity displays altered physico-chemical and mechanical properties resulting in distinct wettability [2] permeability and diffusivity [3] when compared to the soil matrix. The coating characteristics seem to control biopore-matrix mass exchange of water and solutes and quantifying it is essential for better understanding the preferential flow dynamics and for parameterizing and validating numerical simulations. The current mm-scale mass transfer quantification is still methodically limited due to the small spatial size and the heterogeneity of the coatings. Thus, mass exchange at the biopore – soil matrix interface is poorly parameterized in two-domain models [4], which simplifies the material heterogeneity with macroscopic scale semi-empirical first-order expressions. In this proposal 1-05-97 we performed cross flow experiments of wetting and drying processes, controlling input pressure and measuring soil sorptivity. Image analysis will help to quantify water distribution over time and correlate with organic coating hydrophobicity.

Beamline setup and preliminary results

A total of 12 samples were used in cross flow experiments for wetting and drying cycles using cylindrical PTFE sample container with internal diameter ranging from 24 to 34 mm and a height of 50 mm (Fig 1a). The soil samples presented an earthworm burrow in the centre and the dialysis membrane was placed through it. The dialysis membrane was connected to a closed system. Water was pumped in the direction from the bottom to the top of the sample and back to a reservoir placed over a scale. After the wetting experiment was finished (c.a. 1 hour) the system automatically changed to drying process using PEG solution. During the experiment neutrons and X-rays scanning were performed for a voxel size of 10.4 µm and 32 µm, respectively, during 3 minutes for each tomography. In the end of each tomography the sample was rotated back to the initial position. Thus, it was not necessary to use slip rings. In order to optimize data size, the neutrons and X-rays scanning were performed simultaneously from zero to 12 minutes (beginning of wetting process) and from 60 to 72 minutes (beginning of drying process). For all other time instant, X-rays were taken every 9 minutes. The post-processing and analysis of the complementary imaging data is being performed.

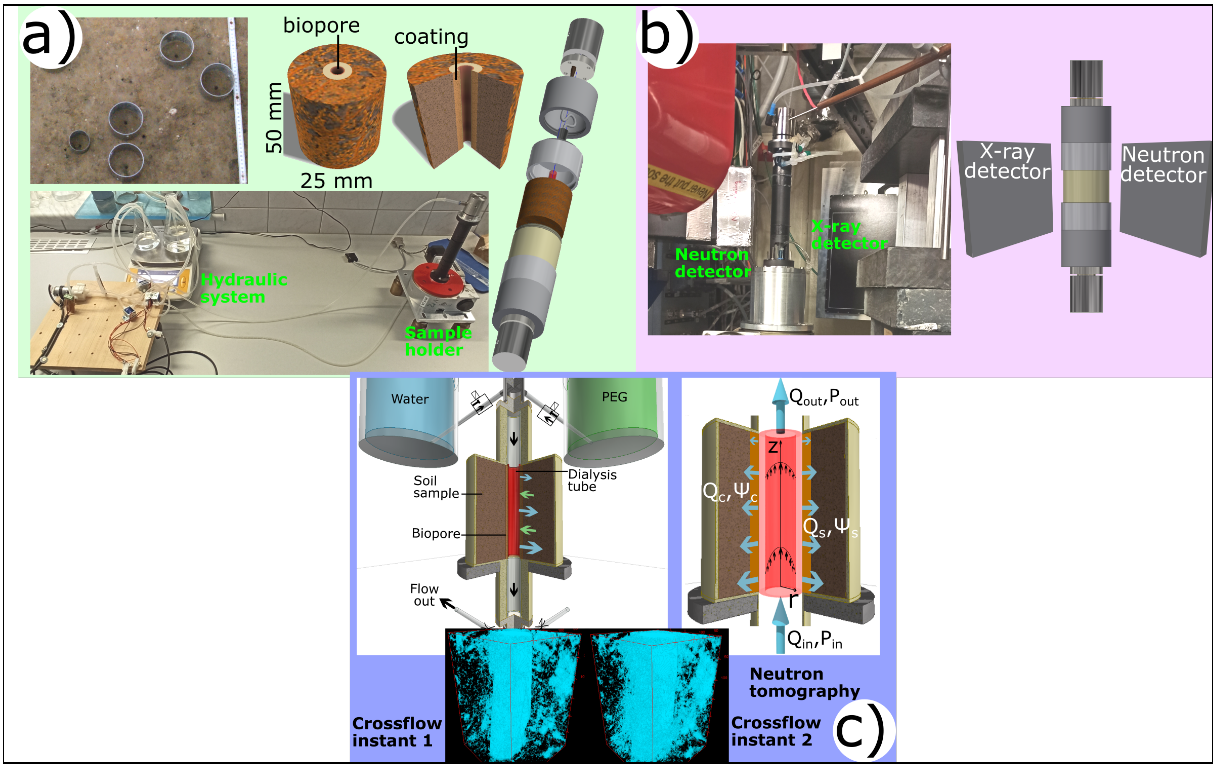

Fig 1. Synchrotron based experiments of the current group's project. a) Soil sampling of coated biopore, development of a sample holder and automated hydraulic system. b) Beam line experiments of simultaneous x-ray and neutron topographies. c) Setup and partial results for crossflow experiments.

References

1.Gerke, H. H. (2006). Preferential flow descriptions for structured soils. Z. Pflanzenernähr. Bodenk., 169: 382-400. doi:10.1002/jpln.200521955.

2.Leue, M., H.H. Gerke, and R.H. Ellerbrock. (2013). Millimetre-scale distribution of organic matter composition at intact biopore and crack surfaces. European Journal of Soil Science, 64, 757–769.

3.Köhne, J. M., H. H. Gerke, S. Köhne, 2002. Effective diffusion coefficients of soil aggregates with surface skins. Soil Sci. Soc. Am. J. 66(5):1430-1438.

4.Gerke, H.H., and M.T. van Genuchten (1993a). A dual-porosity model for simulating the preferential movement of water and solutes in structured porous media. Water Resour. Res. 29(2):305-319